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July 30, 1999

RECEIVED

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

VIA HAND DELIVERY

Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
455 12th Street, S.W., TW-A325
Washington, DC 20554

RE: *Ex Parte Notice: Technical Roundtable On Implementation Of Automatic
Location Identification For Enhanced 911 Technologies, CC Docket No. 94-
102/DA 99-1049*

Dear Ms. Salas:

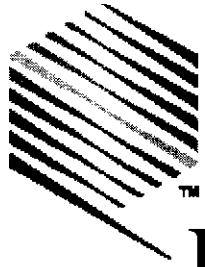
This is to advise you that on June 28th, 1999, Dr. Samir Soliman, Vice President of Technology, QUALCOMM Incorporated presented the attached information at the above-identified open meeting hosted by the sponsored by of the Commission's Office of Engineering and Technology and Wireless Telecommunications Bureau relating to CC Docket No. 94-102.

Sincerely,

J. Breck Blalock

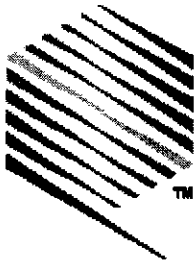
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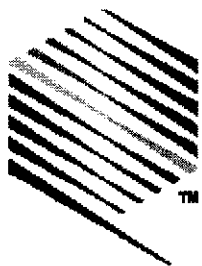
FCC Technical Roundtable: Implementation of ALI for Enhanced E911

Dr. Samir Soliman
Vice President of Technology
QUALCOMM Incorporated
June 28, 1999



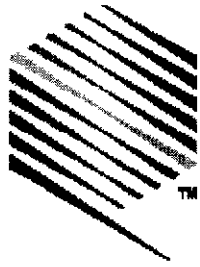
GPS Link Budget

Parameter	Unit	Worst Case	Best Case
User received power in clear view	dBm	-130.0	-120.0
Receiver noise figure	dB	4.0	2.0
Thermal noise density	dBm-Hz	-170.0	-172.0
Clear view C/No	dB-Hz	40.0	52.0
Building penetration and shadowing loss	dB	-20.0	-0.0
Antenna/body loss	dB	-7.0	-3.0
Shadowed C/No	dB-Hz	13.0	49.0

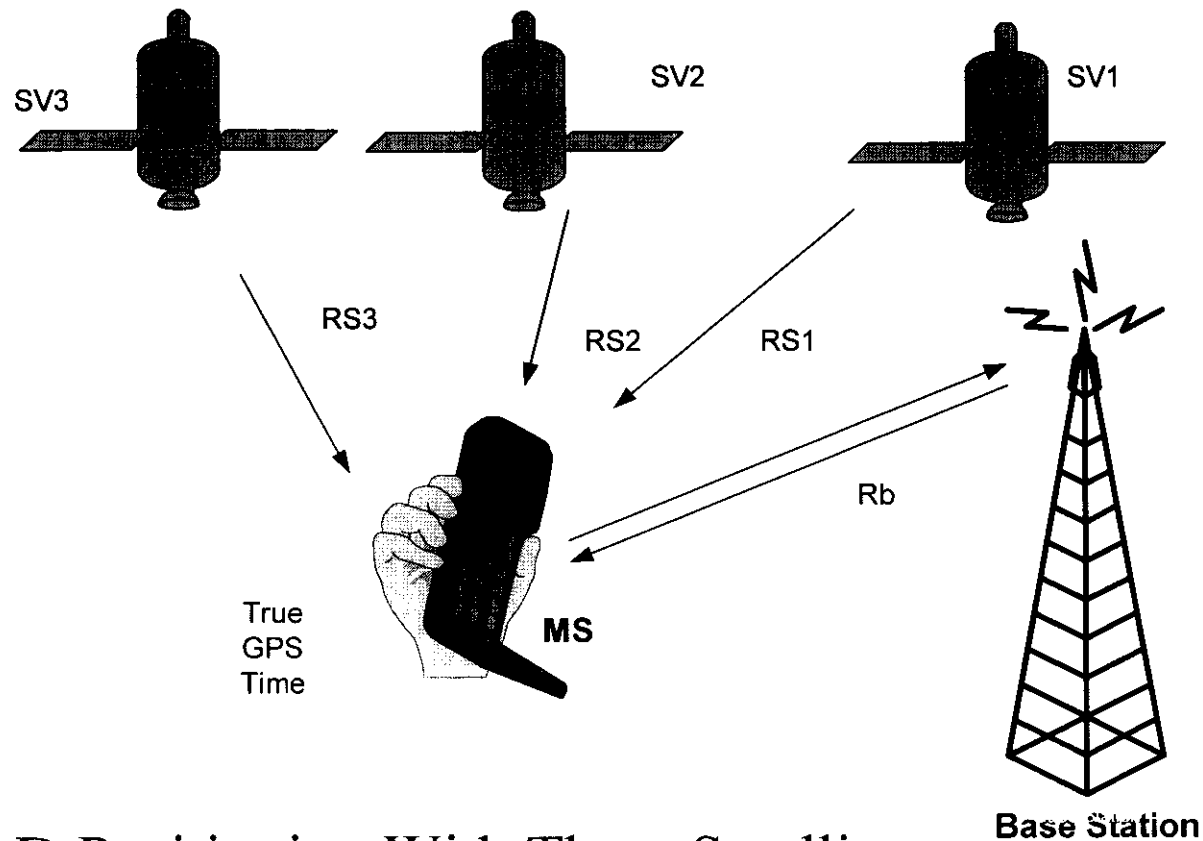


Qualcomm Hybrid Solution

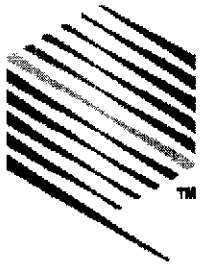
- Method
 - » Fuses GPS and network measurements to produce a location.
- Advantages
 - » Improves availability.
 - » Improves time to first fix.
 - » Solves CDMA roaming issue.



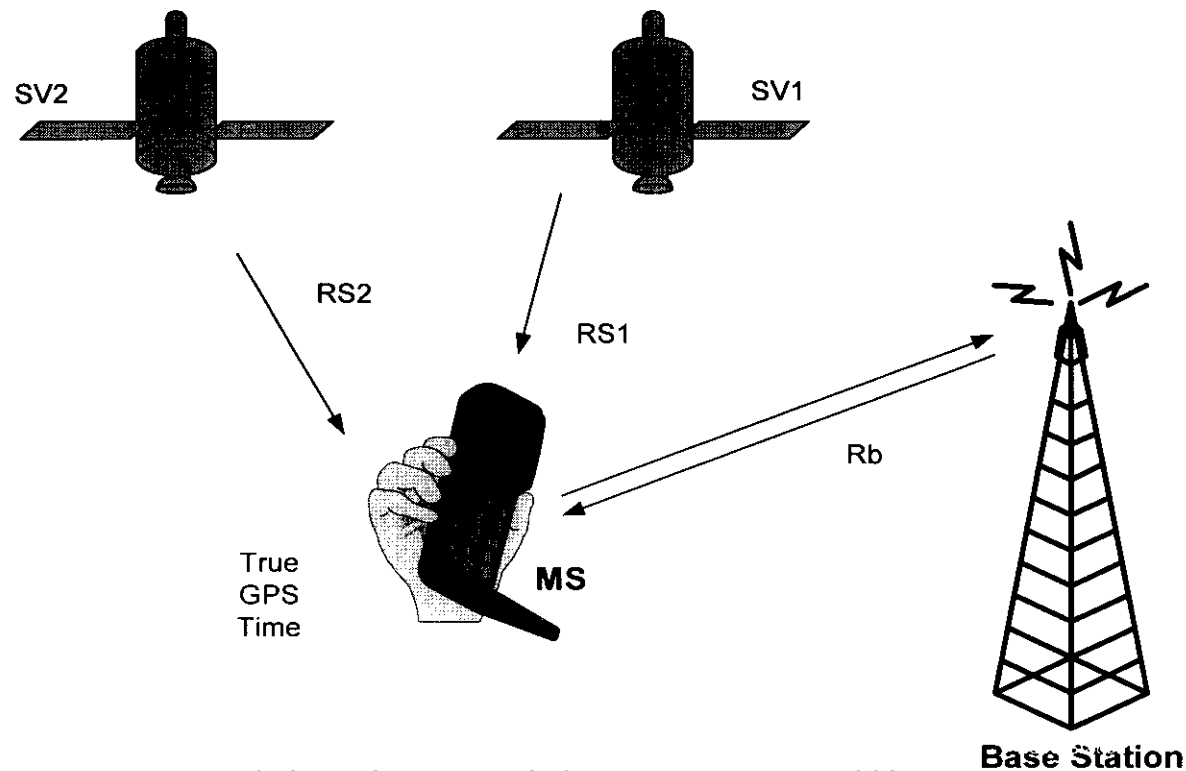
Qualcomm Hybrid Solution (Cont.)



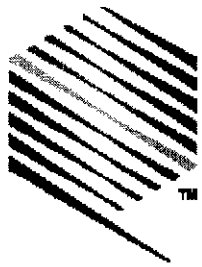
3-D Positioning With Three Satellites



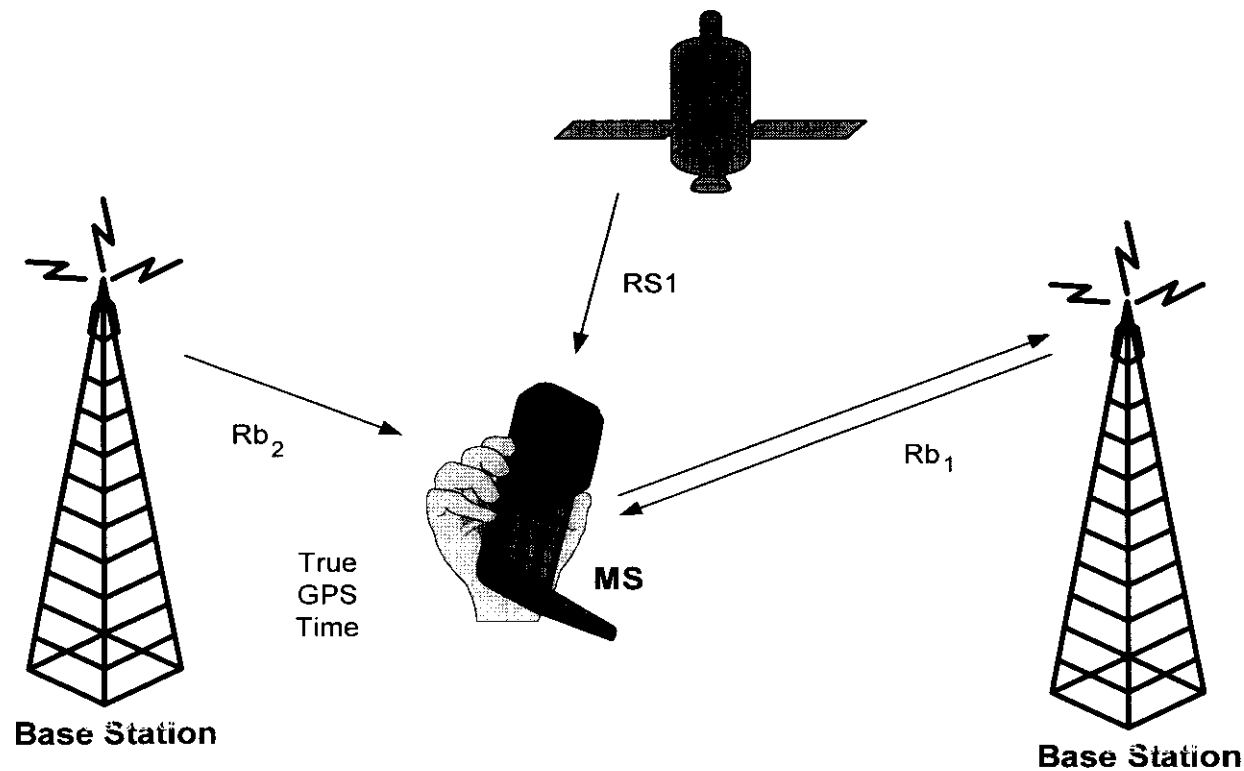
Qualcomm Hybrid Solution (Cont.)



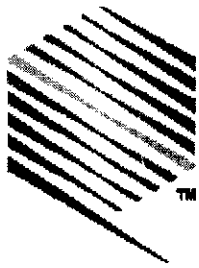
3-D Positioning With Two Satellites



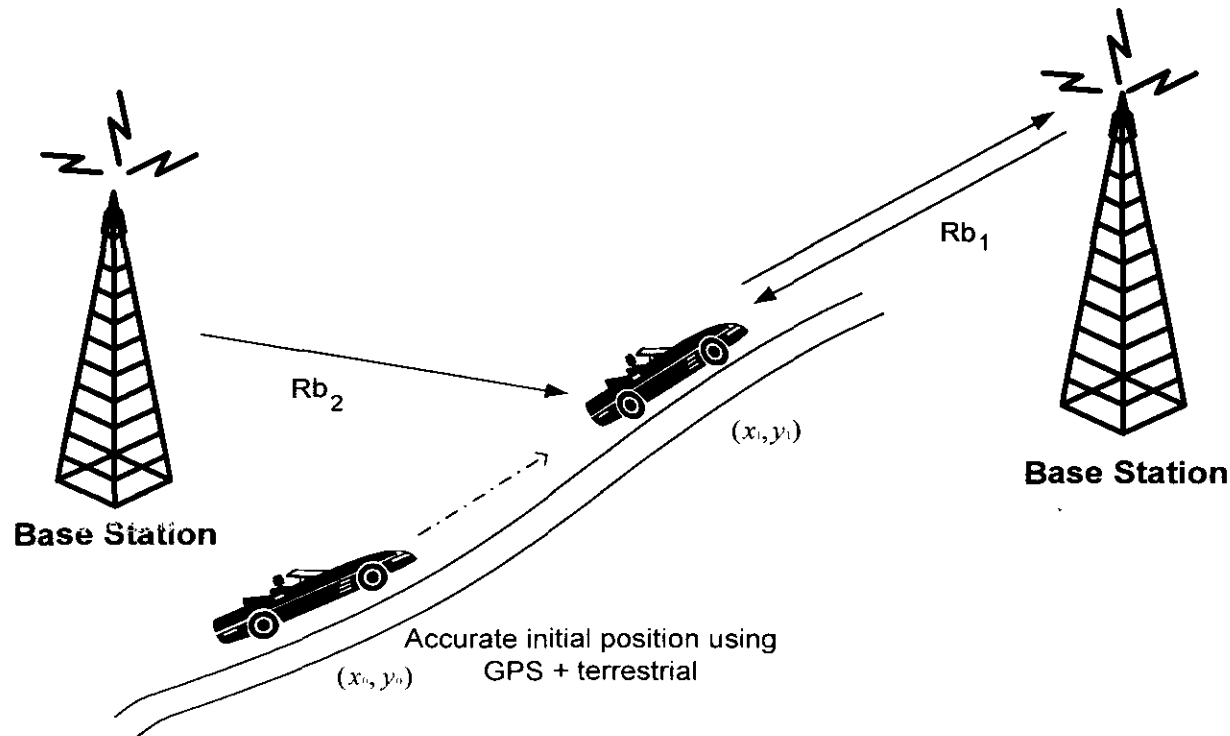
Qualcomm Hybrid Solution (Cont.)



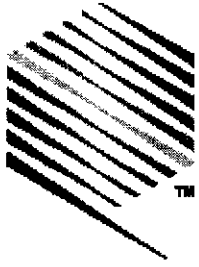
3-D Positioning With One Satellite



Qualcomm Hybrid Solution (Cont.)

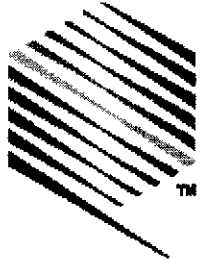


Position Update Using Two Base Stations



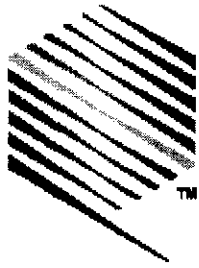
Qualcomm Hybrid Solution (Cont.)

- Timing from round-trip delay (RTD) reduces number of satellites to three.
- RTD for ranging further reduces number of satellites to two.
- Mobile knowledge of exact GPS time speeds up the search process.
- Mobile knowledge of exact GPS time improves sensitivity of the GPS receiver.



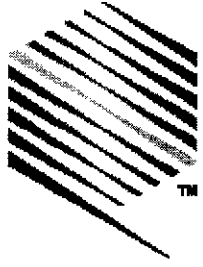
Qualcomm Hybrid Solution (Cont.)

- Network measurements are used to update location without leaving the Voice Channel.
- Existing GPS receivers at base station system are used for differential corrections.



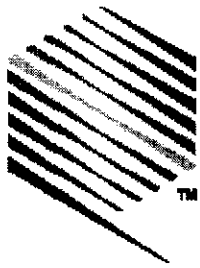
Handset Standards

- Qualcomm has allocated resources to ensure, if carriers desire, that all new handset models introduced after October 2001 comply with existing E-911 mandate specifications.
- Mandate deadline was not intended to preclude deploying more efficient ALI solutions.
- Handset phase-in approach is the most cost-effective approach for carriers and PSAPs.



Handset Standards (Cont.)

- Phase-in approach is consistent with FCC precedents (e.g., TTY).
- Will allow ample time to conduct thorough interoperability testing with PSAPs.
- Handset churn will facilitate rapid deployment of ALI-capable handsets.

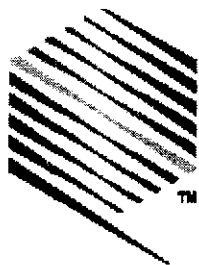


Roaming Issues

Roaming Scenarios		
Roamer type	Carrier Implementation	
	Handset Solution	Network Solution
ALI Capable	No problem†	No problem††
Non-ALI capable	Problem only in AMPS mode	No problem††

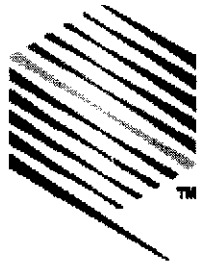
† Pt-to-pt Interface document is in Verification and Validation stage

†† It is still to be seen if a network solution can meet the FCC requirements



Standards Activities

- CDMA community is aggressively addressing the E911 issue in the Standards.
- Qualcomm, Inc. is an active participant in TR45.5 Location Parameters and Signaling Ad Hoc Committees.
- Point-to-point CDMA air interface document (PN 4535) is in Verification and Validation stage.
- Analog operation will be addressed soon.



Accuracy Measure

- Initial testing indicates that the hybrid solution provides better results than either a handset-based or network-based solution.
- Neither wireless network nor GPS guarantee 100% coverage.
- A small percentage of measurements may fail, hence they will have a noticeable impact on the calculated RMS.



Accuracy Measure (Cont.)

- Accuracy measure does not change the actual distribution of location errors, only sugar-coats the reported results.
- Qualcomm supports reverting back to the original FCC interpretation (July 1996): “... 125 meters in 67% of all E911 cases...”.

Hybrid Position Location Technology White Paper

December 1998

80-B6005-1

Revision X2

Samir Soliman



TABLE OF CONTENTS

1. WIRELESS USERS AND E911.....	1
2. FCC MANDATE	1
3. LOCATION APPLICATIONS	2
4. CELLULAR GEOLOCATION.....	3
4.1 Network-based Methods	3
4.2 Handset-based Methods	4
4.2.1 How does a GPS receiver work?	5
4.2.2 Modes of operation	6
5. QUALCOMM PROPOSED APPROACH	9
5.1 Round Trip Delay (RTD)	9
5.2 Pilot Phase Offsets	10
5.3 How Does the Hybrid Approach Work?	11
5.3.1 3-D positioning with three satellites	11
5.3.2 3-D positioning with two satellites.....	12
5.3.3 3-D positioning with one satellite.....	13
5.3.4 Position update using only infrastructure information.....	14
6. GPS RECEIVER SENSITIVITY ENHANCEMENT	15
7. NETWORK REFERENCE MODEL.....	16
8. MOBILE STATION MODIFICATIONS.....	17
9. CONCLUSIONS	18

LIST OF FIGURES

FIGURE 1: How GPS Receivers Work6

FIGURE 2: GPS Receivers Modes Of Operation7

FIGURE 3: Round Trip Delay Measurements..... 10

FIGURE 4: RTD To Other Base Stations 10

FIGURE 5: Pilot Phase Difference..... 11

FIGURE 6: 3-D Positioning With Three Satellites 12

FIGURE 7: 3-D Positioning With Two Satellites. 13

FIGURE 8: 3-D Positioning With One Satellite 14

FIGURE 9: Network Reference Model..... 16

FIGURE 10: MS/GPS Block Diagram..... 18

LIST OF TABLES

TABLE 1: Summary Of GPS Link Budget..... 15

1. WIRELESS USERS AND E911

In January 1968, a three-digit telephone number, "9-1-1", was introduced throughout the United States for use as a "universal emergency number". Upon receiving a 9-1-1 call, the dispatchers alert medical, fire, and/or police for assistance as required. In March 1973, the 9-1-1 service was further enhanced (E911) to provide "automatic" location and calling telephone number information to the Public Safety Answering Point (PSAP). This improvement enables PSAP to provide emergency services even if the person making the call is unable to give location information.

Presently, when a wireless E911 call is made, the end-office treats the incoming call as if it were dialed from a fixed wireline phone with a substituted phone number. The substitute number is assigned as one per cell site, one per cluster of cell sites, or possibly one per system. The PSAP operators have to rely on the location information given by the caller before they can respond to emergency requests. The problem arises because routing is not exact and can cross PSAP jurisdictions. In addition, serving cells often encompass several square miles thus making it much harder to determine the exact location of the caller in distress.

Two pieces of information are missing in the wireless networks: Automatic Location Identification (ALI) and Automatic Number Identification (ANI). The first is used to determine the geographical location of the caller, and the second is used to call the user back if the original call gets disconnected. Wireless emergency calling (E911) services will significantly improve when new FCC rules governing wireless call origination tracking go into effect.

2. FCC MANDATE

In June 1996 the FCC adopted a report and order for enhanced E911 wireless service. On December 23, 1997, the FCC issued a revised version of the report and order. Highlights are as follows:

1. Within twelve months after the effective date of the rules, the Commission will require that cellular, broadband PCS and geographic area Specialized Mobile Radio (SMR) licensees transmit to the PSAP E911 emergency calls from a handset that transmits a mobile identification number (MIN) (or its functional equivalent) without any interception by the carrier for credit checks or other validation procedures.
2. Beginning twelve months (and completed within eighteen months) after the effective date of the rules, the FCC requires cellular, broadband PCS and

geographic SMR licensees to offer certain E911 enhancements. These E911 features include the ability to relay a caller's telephone number (call back the E911 caller if a call is disconnected). Also, carriers must be capable of routing E911 calls to an appropriate PSAP.

3. Within five years after the effective date of the rules, the location of the mobile station (MS) making the emergency call must be provided to the qualified PSAP in two-dimensions and have an accuracy within a 125 meter radius measured using root mean square (RMS) methods. According to the FCC, a request is qualified if and when (1) a PSAP indicates it has the capability to receive and utilize the number and location passed along by the wireless carrier, and (2) there is a cost-recovery mechanism in place.

In the revised report, the FCC temporarily suspended enforcement of the Text Telephone (TTY) requirements for 12 months until October 1, 1998, but only for digital systems and subject to conditions that protect consumers, encourage compliance, and ensure minimum delay. Also, the FCC recognized that the commercial Mobile Satellites Services (MSS) industry is still in its infancy, hence the FCC affirmed its decision NOT to impose E911 requirements upon MSS providers at this time.

3. LOCATION APPLICATIONS

To the average consumer, location services may be just "another high-tech feature" and could be perceived in the same way cell phones and computers were viewed ten years ago. Nevertheless, to wireless carriers, location applications have become increasingly important as they look for ways to meet the FCC mandate and to offer new revenue-generating services to their customers. Potential location applications include the following:

1. Location sensitive billing: The wireless carriers can target new market segments by enabling accurate price differential based on the caller location. This enables wireless carriers to compete with wireline carriers by offering comparable rates when the caller is at home or in the office.
2. Location-based information services: For a monthly fee, a user can call the service center to ask for driving directions or get advice on restaurants, hotels, department stores, and gas stations. The service center can also respond to emergency requests by notifying police/fire personnel or ordering a tow truck in the case of a vehicle breakdown.
3. Network planning: Statistics from the wireless network operation can be used to plan expansion or deployment of an entirely new network.

4. Dynamic network control: The collected statistics can be used to dynamically adjust network parameters to accommodate network load change due to callers' behavior.
5. Fraud management: Fraud can have a devastating impact on wireless carriers by reducing profits and undermining the customer's confidence. Location information helps operators ensure prompt detection and tracking leading to swift apprehension of the culprit.
6. Fleet management and asset tracking: Asset tracking represents a cost savings that almost equals the value of the asset. It gives the fleet owner the ability to constantly locate company vehicles, to instantly communicate with the driver, or at the push of a button, to update the status of the engine, powertrain, door locks, etc.
7. Real-time traffic updates: Information received can be sent to traffic management centers to help reduce traffic jams and speed travel.

4. CELLULAR GEOLOCATION

The cellular geolocation problem can be solved using either network-based methods or using handset-based methods.

4.1 Network-based Methods

Network-based solutions rely on the signal transmitted from the MS and received at multiple fixed base stations (BSs). This can be accomplished by two general methods: Angle of Arrival (AOA) and Time of Arrival (TOA). In the case of AOA, the position of the mobile is estimated based on the intersection of multiple lines of bearing (LOB) calculated by direction finding antenna arrays. The arrays are located on nearby BSs of exact known location. Accuracy of position estimate depends upon the angular resolution and transmitter location relative to the BSs. The best estimate usually results when LOBs are at right angles to one another.

Using the TOA method, the position of the mobile is estimated based on the timing of signals arriving at multiple BSs. The mobile will lie on a hyperbola defined by the difference in time of arrival of the same signal at different BSs. Accuracy of position estimate depends on accurate synchronization and signal structure (bandwidth, etc.). The best estimate results when the mobile is in the middle of the BSs' configuration.

Network-based methods suffer from multipath, diffraction, and weak signal conditions. The list below summarizes the disadvantages of a network-based solution:

1. Network-based position location solutions are vulnerable to multipath propagation which is typical in terrestrial communication systems. Multipath propagation can not only cause huge errors in the estimated location of the MS, but also results in signal attenuation that may lead to situations where the location of the MS can not be found.
2. Network-based solutions require that the MS be visible to three or more BSs simultaneously. This requirement contradicts CDMA network designs, which use maximum possible separation between cell sites to minimize infrastructure costs. Thus, in a typical CDMA network, the position location coverage area can be a small subset of the communication coverage area.
3. The position location coverage area can be extended by forcing the MS to transmit more power than required for communications. This results in some improvement in the coverage area, but can cause huge amounts of interference that may degrade the performance of the CDMA system.
4. Most cellular infrastructure equipment is not suited, nor intended, to provide the higher accuracy time or angle measurements needed for network-based position location. Currently, the IS-95 timing specifications are not tight enough to provide the accuracy required for some position services applications. IS-95 states "All base stations should radiate pilot pseudo noise (PN) sequences with ± 3 microseconds (μs) of CDMA System Time and shall radiate the pilot PN sequence within $\pm 10 \mu s$ of CDMA System Time. All CDMA channels radiated by a base station shall be within $\pm 1 \mu s$ of each other."
5. Repeaters and signal enhancement techniques can cause problems.
6. Cellular and PCS networks are planned and deployed based on forward (down) link coverage, while location networks are planned based on reverse (up) link coverage. Hence using a network-based solution will require RF tuning and maintenance of both links of the network resulting in doubling the effort.
7. Availability in hard handoff areas is questionable due to multi-carrier, multi-system, etc.

4.2 Handset-based Methods

In this section we focus on handsets with Global Positioning System (GPS) capabilities. The space segment of GPS consists of a constellation of 24 satellites (plus one or more in-orbit spares) circling the earth every 12 hours. The satellites are at an altitude of 26,000 km. Each satellite transmits two signals: L1 (1575.42 MHz)

and L2 (1227.60 MHz). The L1 signal is modulated with two PN codes—the protected (P) code and the coarse/acquisition (C/A) code. The L2 signal carries only the P code. Each satellite transmits a unique code, allowing the receiver to identify the signals. Civilian navigation receivers use only the C/A on the L1 frequency.

4.2.1 How does a GPS receiver work?

The idea behind GPS is to use satellites in space as reference points to determine location. By accurately measuring the distance from three satellites, the receiver “triangulates” its position anywhere on earth. The receiver measures distance by measuring the time required for the signal to travel from the satellite to the receiver. However, the problem in measuring the travel time is to know exactly when the signal left the satellite. To accomplish this, all the satellites and the receivers are synchronized in such a way that they generate the same code at exactly the same time. Hence, by knowing the time that the signal left the satellite, and observing the time it receives the signal based on its internal clock, the receiver can determine the travel time of the signal. If the receiver has an accurate clock synchronized with the GPS satellites, three measurements from three satellites are sufficient to determine position in three dimensions. Each pseudorange (PR) measurement gives a position on the surface of a sphere centered at the corresponding satellite. The GPS satellites are placed in a very precise orbit according to the GPS master plan. GPS receivers have a stored “almanac” which indicates where each satellite is in the sky at a given time. Ground stations continuously monitor GPS satellites to observe their variation in orbit. Once the satellite position has been measured, the information is relayed back to the satellite and the satellite broadcasts these minor errors “ephemeris” along with its timing information as part of the navigation message.

It is very expensive to have an accurate clock at the GPS receiver. In practice, GPS receivers measure time of arrival differences from four satellites with respect to its own clock and then solve for user position and clock bias with respect to GPS time. This involves solving a system of four equations with four unknowns given the PR measurements and satellite positions (satellite data) as shown in Figure 1. In other words, due to receiver clock error, the four spheres will not intersect at a single point. The receiver then adjusts its clock such that the four spheres intersect at one point.

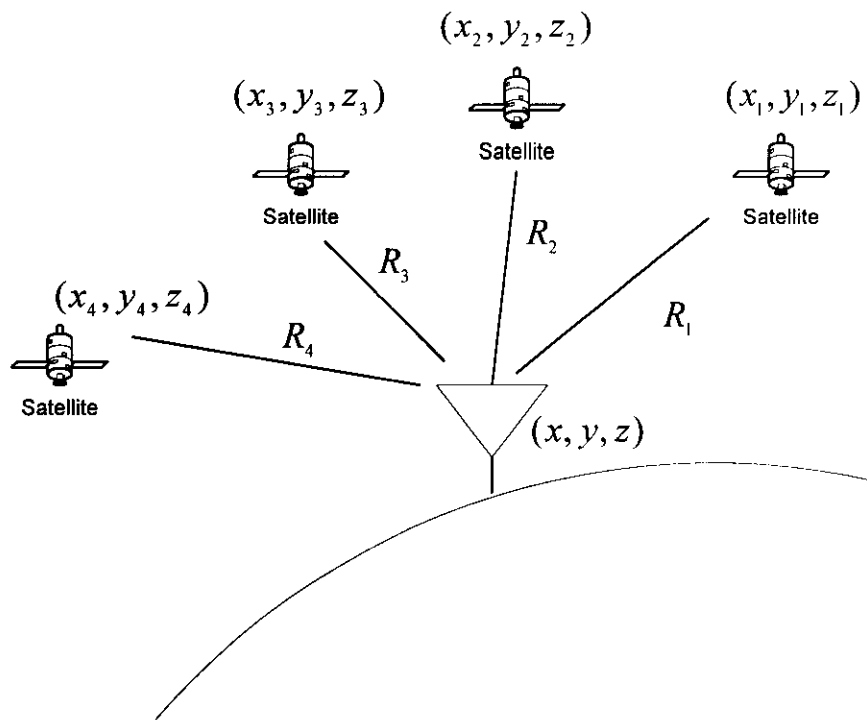


Figure 1: How GPS receivers work

4.2.2 Modes of operation

GPS receivers can operate in several modes. Figure 2 lists the different modes of operations.

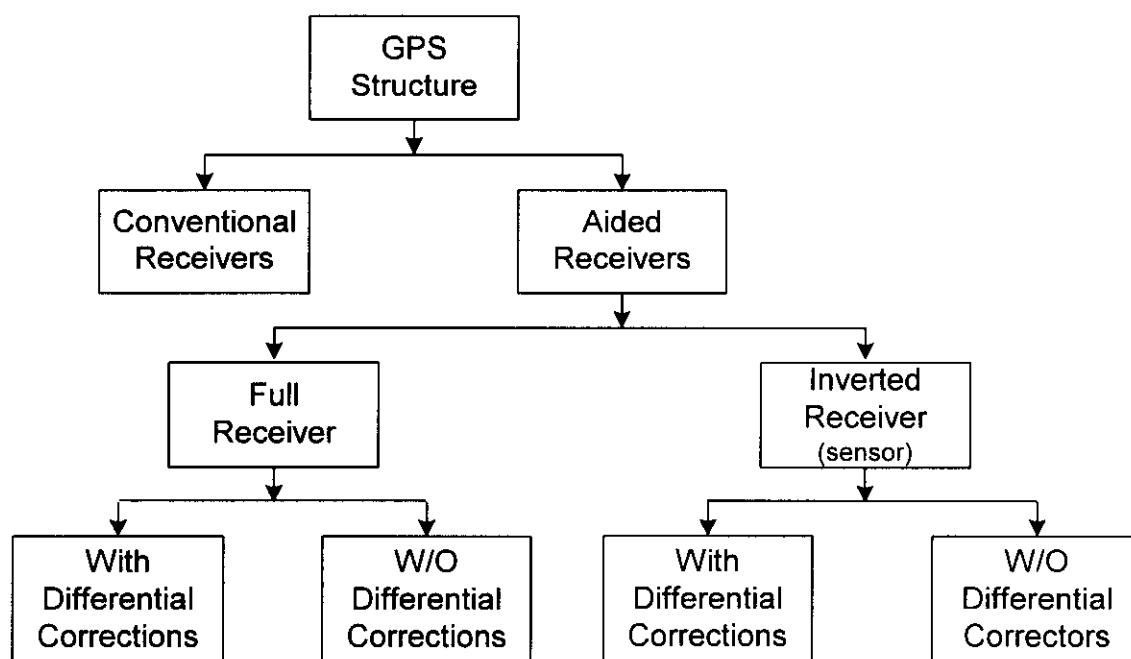


Figure 2: GPS receivers modes of operation

4.2.2.1 Conventional (stand alone)

A conventional GPS receiver provides accuracy within approximately 100 meters (two-dimensional rms, 95%). A stand-alone GPS receiver operates as follows:

1. Searching for a satellite in the frequency domain
2. Detecting a satellite PN code in a frequency bin
3. Acquisition and tracking of the carrier frequency
4. Acquisition and tracking of navigation data transitions, data subframes and frame boundaries
5. Reading the clock corrections and ephemeris data
6. Repeat steps (1)-(5) for all satellites in view
7. Measure PRs to all detected satellites
8. Compute the position using PRs and satellite data

The time required by a conventional receiver to accomplish these tasks depends upon the state of the GPS receiver. Typically, there are three common states:

1. Cold Start State: The GPS receiver has no GPS almanac. The GPS almanac gives an approximate satellite ephemeris. Almanac data permit the user to select the

best set of satellites or simply to determine which satellites are in view. It takes the receiver 12.5 minutes to download the almanac of the entire GPS constellation. Without an almanac, the GPS receiver must search all 24 satellites and must conduct the widest frequency search to acquire the first satellite. The width of the search window is determined by satellite Doppler and receiver local oscillator offset.

2. Warm Start State: In this state, it is assumed that the receiver has a GPS almanac which will reduce the search in the frequency domain (almanac contains satellite Doppler). The time required to generate a position is determined by the time to receive clock correction and ephemeris data for each satellite. The ephemeris is broadcasted every 30 seconds and is valid for approximately two hours. Hence, a GPS receiver that starts in this state will be able to determine a position in about 30 seconds.
3. Hot Start State: In this state, the receiver is assumed to have ephemeris and clock corrections for all satellites in view. The receiver needs to do two steps: (1) measure PRs to all detected satellites, and (2) compute the position using PRs and satellite data. It is possible to determine a position fix in less than one second if the search algorithm uses information from the first acquired satellite to calibrate its own local oscillator frequency error.

4.2.2.2 Aided GPS receivers

To speed up satellite acquisition in frequency domain, the receiver needs to know both satellite Doppler and local oscillator frequency. Also, to reduce the search in the time domain, the receiver needs to know almanac, approximate location, and approximate time of the day. Finally, to calculate position, the receiver needs to collect ephemeris of satellites in view. A GPS receiver is working in aided mode if one or more of the above pieces are sent to it using the communication link.

There are two types of aided GPS receivers: a full receiver and a sensor receiver. In the case of a full receiver, the location fix is calculated at the unit. Whereas, in the case of a sensor, only PR measurements are collected and sent over the communication link to the position determination entity (PDE) which in turn calculates the sensor's location. Differential correction can be used for both full receiver and sensor configurations.

4.2.2.3 Differential GPS (DGPS)

In spite of all the measures taken to make the GPS system as accurate as possible, there are sources of errors that cannot be eliminated using established models. Selective availability (intentionally introduced error), ionospheric delay, tropospheric delay, and satellite clock error are the most significant sources of errors. Differential GPS (DGPS) is a means of removing correlated (common) errors

between two or more receivers performing range measurements to the same set of satellites. One receiver (reference), that knows its position accurately, determines the difference between that known position and the position determined by a GPS receiver at discrete times. This error measurement (differential correction) is then passed to other receivers in the area to adjust its calculated position to compensate for the common errors. DGPS will eliminate errors introduced by selective availability, variations in the atmospheric propagation, and satellite clock errors and may result in a 10 meter (two-dimensional rms, 95%) position error.

5. QUALCOMM PROPOSED APPROACH

The network solution and the GPS solution complement each other. For example, in rural and suburban areas not too many BSs can hear the phone, but a GPS receiver can see four or more satellites. Conversely, in dense urban areas and inside buildings, GPS receivers do not detect enough number of satellites, but the phone can see two or more BSs. The Qualcomm proposed solution takes advantage of cellular/PCS information that is already available to both the phone and the network to improve both the accuracy and availability of the positioning service.

Among the information that Qualcomm plans to use are: (1) round trip delay (RTD) and (2) pilot phase offsets.

5.1 Round Trip Delay (RTD)

The pilot timing on the forward link of each sector in the BS is synchronized with GPS system time, T_{sys} . The MS time reference is the time of occurrence, as measured at the MS antenna connector, of the earliest arriving usable multipath component being used in the demodulation. The MS time reference is used as the transmit time of the reverse traffic and access channels.

As shown in Figure 3, the mobile uses the received time reference from the serving BS as its own time reference. Accounting for its own hardware and software delays, the MS transmits its signal such that it is received back at the serving BS delayed by a total of 2τ , assuming reciprocity of forward and reverse links. The total delay is measured at the BS by correlating the received signal from the MS with the referenced signal at time T_{sys} . The measured RTD corresponds to twice the distance between the mobile and BS. Round trip delay to other BSs can be measured also, but they do not correspond to twice the distance between the mobile and other BSs as shown in Figure 4.

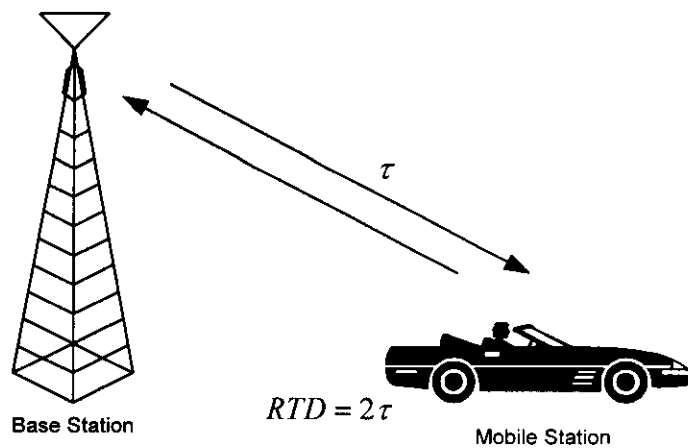


Figure 3: Round trip delay measurements

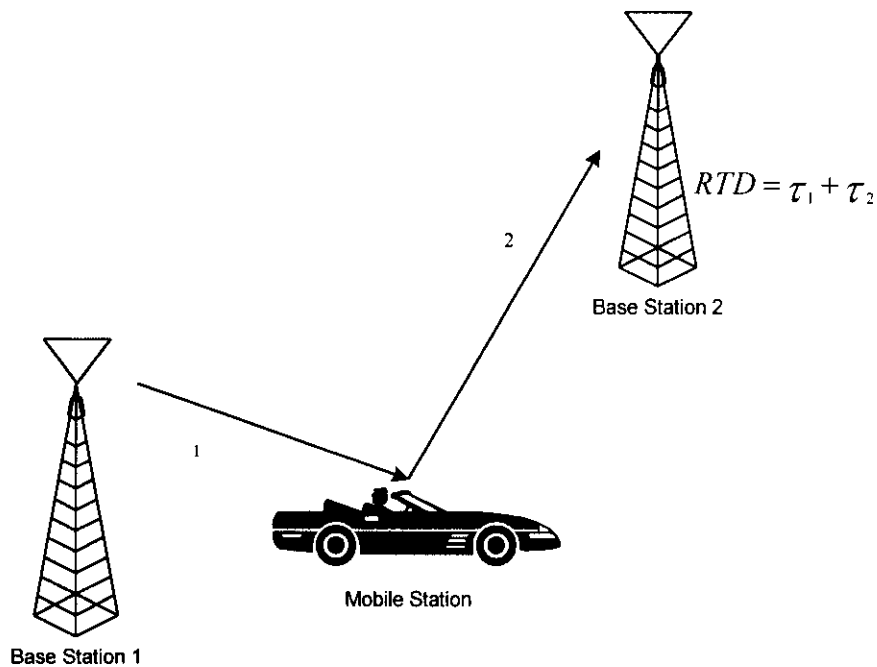


Figure 4: RTD to other base stations

5.2 Pilot Phase Offsets

The MS is continuously searching active and neighboring pilots. In the process it measures the PN phase difference (delay) between each pilot and the reference (earliest arrival) pilot.

The pilot PN phase difference is the same as time difference of arrival (TDOA) of the two pilots from the two BSs as shown in Figure 5.

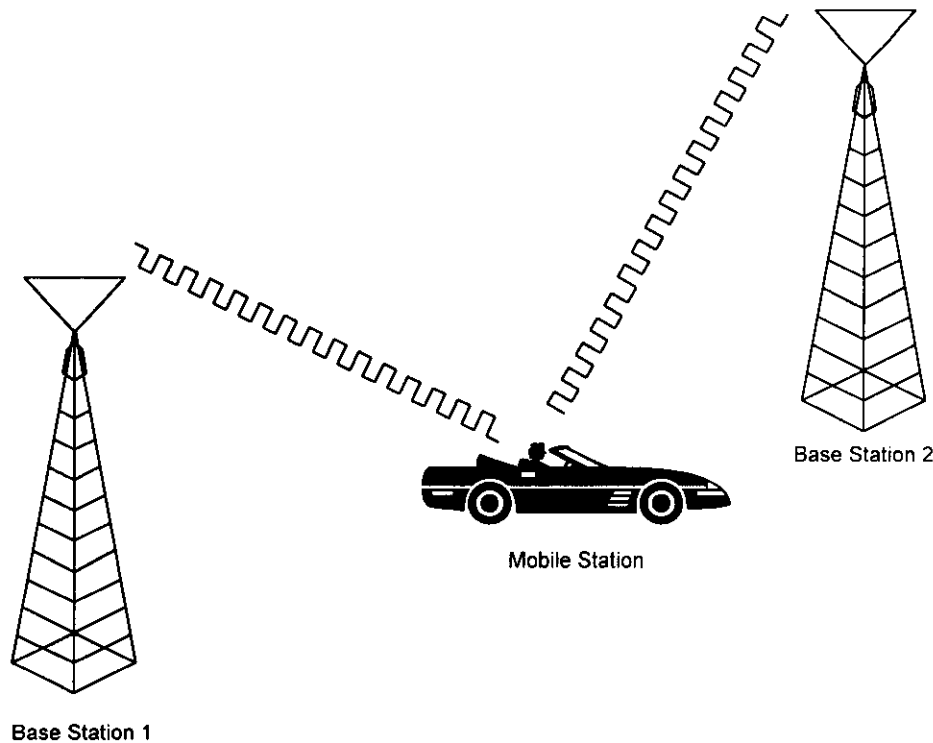


Figure 5: Pilot phase difference

5.3 How Does the Hybrid Approach Work?

The proposed hybrid approach merges GPS and network solutions to meet not only the FCC E911 mandate, but also other location-based service requirements. The MS collects measurements from the GPS constellation and cellular/PCS network and sends the information back to an entity in the network that fuses the measurements together to produce an accurate 3-D position.

5.3.1 3-D positioning with three satellites

As shown in Figure 6, since the MS is receiving CDMA signals from at least one BS, it will acquire system time. Its sense of system time is delayed with respect to true system time at the serving BS by the propagation delay τ between the mobile and BS. Once the mobile tries to access the system, or is on the traffic channel, the propagation delay τ is estimated by $\frac{RTD}{2}$. This estimate can be used to adjust the mobile system time to correspond to "true" GPS time. Now the mobile clock is

synchronized with GPS time; hence only three measurements from three satellites are needed (See Section 4.2.1.) Note that multipath does not impact the performance of the system because the mobile system time is shifted from GPS time by τ regardless of whether the signal took a direct path or a reflected path.

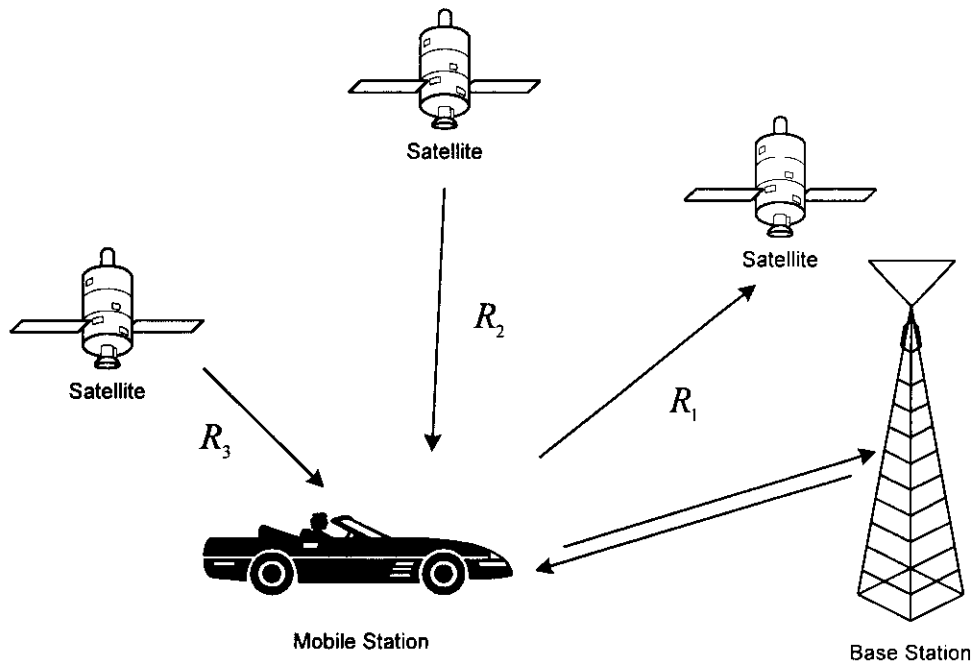


Figure 6: 3-D positioning with three satellites

5.3.2 3-D positioning with two satellites

In addition to using the RTD to the serving BS for timing, it can also be used for ranging as shown in Figure 7. The distance to the serving BS is given by $R_3 = C\tau$ where C is the speed of light. Multipath here will impact positioning accuracy. Note that under certain geometry scenarios, we may get two ambiguous solutions. The ambiguity can be resolved by using either sectorization or forward link information. For example, pilot PN phase difference of a neighboring pilot can be used to resolve the resulting ambiguity.

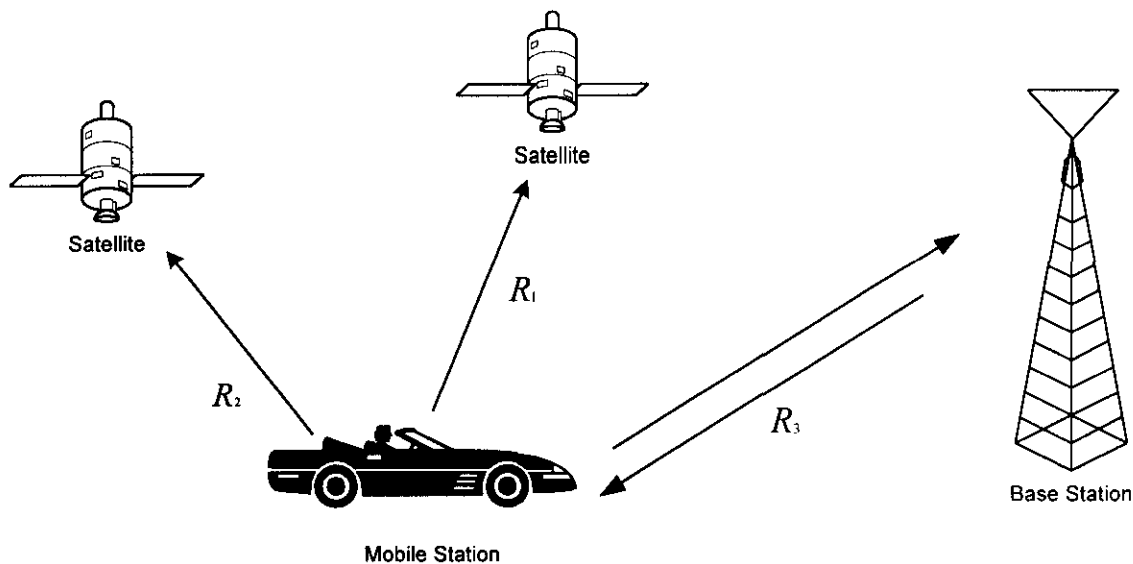


Figure 7: 3-D positioning with two satellites

5.3.3 3-D positioning with one satellite

In this scenario, the proposed approach requires one additional measurement from the cellular/PCS network. This additional measurement could be either a second RTD measurement, or a pilot phase offset on the forward link as shown in Figure 8. To reduce the impact of multipath on the calculated position, the phone is asked to report the pilot phase of the earliest arriving path.

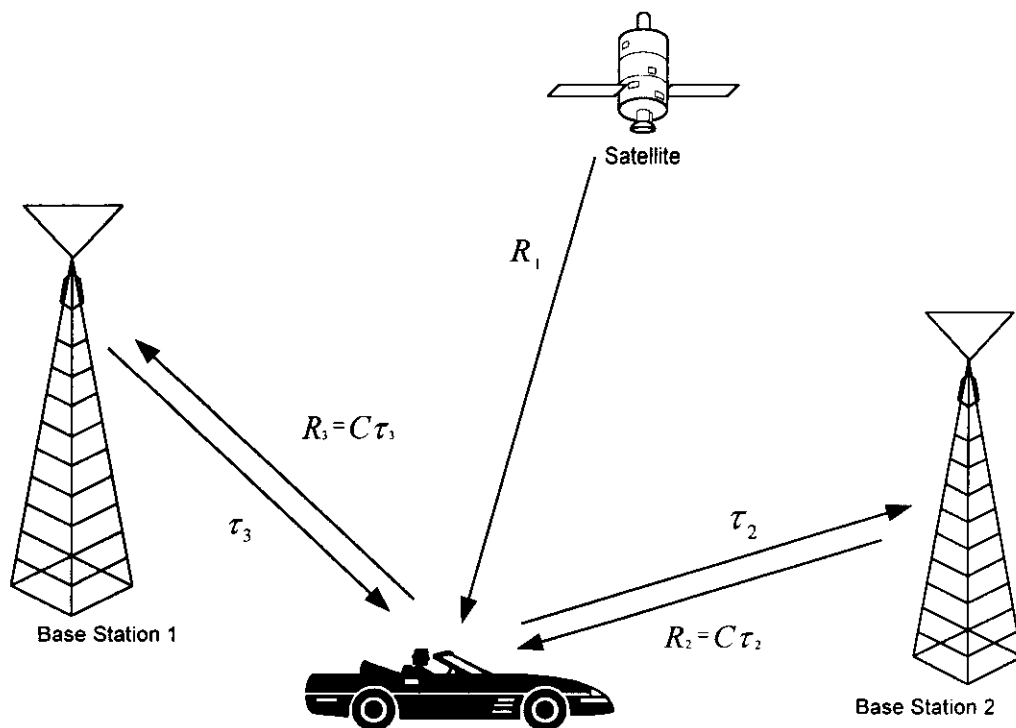


Figure 8: 3-D positioning with one satellite

5.3.4 Position update using only infrastructure information

Infrastructure information alone can be used to update the location of the MS. This "free wheeling" concept is useful in tracking modes because it reduces the amount of time the MS is away from the cellular/PCS channel while measuring the signal from the GPS channel. This way, there is no degradation to call delivery rate or voice quality.

An initial and accurate position is determined using information from both the GPS constellation and infrastructure as discussed earlier. Afterward, and until it is decided that the "free wheeling" solution is no longer reliable, the MS uses infrastructure measurements only to update its position. It can be shown that forward or reverse link information from two BSs are enough to update the 2-D position of the MS. Because of the inherent channel impairments, the update will degrade with time and eventually a fresh GPS constellation-based solution will be needed.

6. GPS RECEIVER SENSITIVITY ENHANCEMENT

The specification for the GPS signal level under clear view of the sky is -160 dBW. Building penetration, shadowing, and foliage could degrade the signal by more than 20 dB. Table 1 is a sample link budget for a typical GPS receiver.

Table 1: Summary of GPS link budget

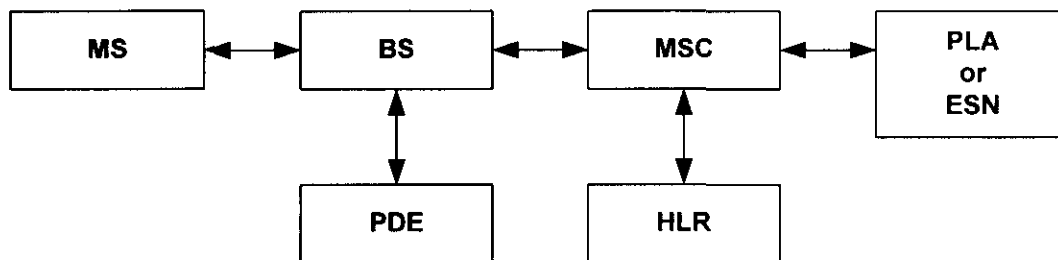
Parameter	Unit	Min. Value	Max. Value	Equation
Satellite antenna input power	Watt	21.88	87.11	
	dBW	13.40	19.40	Pt
Satellite antenna gain (worst case)	dB	13.40	15.40	Gs
EIRP	dBW	26.80	34.80	C=Pt+Gs
Polarization mismatch loss	dB	-3.40	-3.40	Lp
Atmospheric loss	dB	-2.00	-0.30	La
GPS frequency	MHz	1575.42	1575.42	fo
Distance to satellite	km	25150.00	25150.00	d
Free space propagation loss	dB	-184.40	-184.40	Lf=20log($\lambda/4\pi d$)
User linear antenna gain	dB	3.00	3.00	Gu
User minimum received power	dBW	-160.00	-150.30	R=C+Lp+La+Lf+Gu
Receiver noise figure	dB	2.00	3.00	
Thermal noise density	dBW-Hz	-202.00	-201.00	No
Clear view C/No	dB-Hz	41.00	51.70	C/No=R-No
Building penetration and shadowing loss	dB	-20.00	-20.00	F
Shadowed C/No	dB-Hz	21.00	31.70	C'/No=C/No-F

Conventional GPS receivers typically integrate coherently over one millisecond (one code period) and non-coherently for six milliseconds. Thus, a conventional GPS receiver can only acquire signals above -166 dBW. Weaker signals require more processing gain (longer integration) for successful acquisition. Knowing "true" GPS time at the mobile and the approximate range to the satellite will enable the phone to integrate over 20 milliseconds (one navigation bit period). Furthermore, if the BS can predict the bit sequence for some parts of the navigation message, the bit polarity can be sent to the MS to help with integrating over multiple bits. In addition to the sensitivity enhancement, knowing "true" GPS time at the MS reduces the time required to acquire the GPS signal for a given satellite. The serving BS sends information regarding the search window center and the search window size to the MS. Therefore, the MS needs only to search a small window in the time domain rather than the whole code space. For a MS at four miles distance from the BS, the

search window size for a satellite with a 60° elevation angle is only 20 chips. This would reduce search time per satellite by a factor of 50.

7. NETWORK REFERENCE MODEL

For an emergency services network, as in any other network, it is important to define a reference model (i.e., network architecture) in which a set of functional entities and interfaces between them are identified. Figure 9 describes a functional network model for determining the location of a MS in cellular/PCS network.



MS: Mobile station
BS: Base station system
MSC: Mobile switching center
PDE: Position determination entity

HLR: Home location register
PLA: Position location application
ESN: Emergency service network

Figure 9: Network reference model

One of the key elements of an emergency services network is the PDE. The proposed architecture is flexible enough to allow the location functionality to be built in a variety of configurations using different radio location technologies.

Locating a wireless terminal (a MS, a personal station, etc.) involves two functions: (1) signal measurement function, and (2) position calculation function. Signal measurement can be performed at either the MS, the BS, or both. The positioning calculating function uses the signal measurement to compute the MS location along with some sort of figure of merit or confidence level associated with the calculations. These two functions are radio related and should stay in the radio access part of the CDMA network. The list below gives several advantages to placing the PDE on the BS side of the A interface (interface between BS and MSC):

1. Takes advantage of air interface enhancement: The position determination entity (PDE) is an entity that deals with radio related functions and should stay in the radio access part of the CDMA network (i.e., at the BS). This would allow the PDE to take full advantage of any future air interface enhancement. This could

lead to better, faster, and more accurate mobile position location information when needed.

2. Facilitates mobile-assisted location determination: For all radio location technologies, MS assistance is required in providing location measurement and other subscriber information to the PDE for position determination. The exchange of this and any other information between the MS and the network is facilitated if the PDE is connected directly to the BS.
3. Reduces A interface signaling: Placing the PDE on the mobile switching center (MSC) side of the A Interface requires the BS to send the raw signal measurements to the MSC via the A Interface. Placing it on the BS side will eliminate the need to send the raw data and hence minimizes the impact on the A Interface signaling traffic.
4. Improves time to first fix: Sending raw signal measurement from the BS to MSC introduces additional delay and hence degrades the time to first fix.
5. Coordinates BS call control tasks: Some location services applications may require coordination between call related tasks such as handoff and signal measurement functions. This coordination is better served if the PDE is located at the BS.
6. Allows for all radio location technologies: There is less concern about raw data formatting between BS and MSC. The format may be different for different radio location technologies.
7. Availability of location information after call setup: Call control is primarily the responsibility of the MSC while location information (e.g., E911 Phase II location information) will become available only after call setup, regardless of the type of technology being used. This means that different messages, protocols and procedures are used to support call-related and location-related functions. Therefore, there is no need to get the MSC involved in location information exchange between the PDE and the MS. The transfer of this information between different entities would occur much faster and in a more reliable manner if the PDE is attached to the BS.
8. Backhaul capacity: In some network architecture, it is appropriate to place the PDE at the BS to reduce the impact on the backhaul network capacity.

8. MOBILE STATION MODIFICATIONS

To build a GPS sensor, one must design a radio that can receive a GPS signal at 1.57542 GHz. The received RF signals are down-converted to IF and then to digital

signals. These digital signals are processed to produce range information. Figure 10 is a block diagram of an integrated GPS/MS.

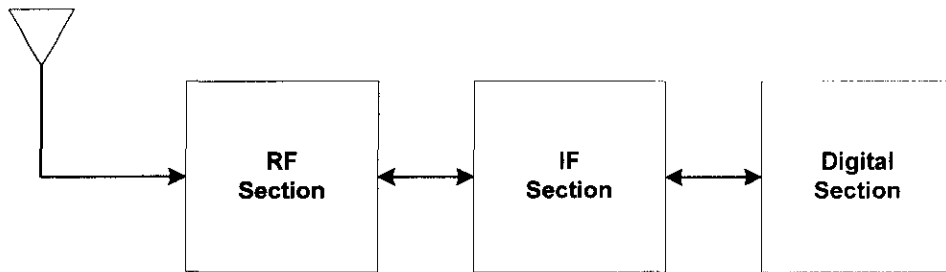


Figure 10: MS/GPS block diagram

An antenna subsystem can be designed to support both GPS and cellular/PCS operations. The RF section of the first generation MS/GPS will have separate RF branches, one for cellular/PCS and one for GPS.

Since the trend is towards higher levels of integration, there is a need to share resources with other parts of the phone system. The second generation MS/GPS may have a common RF chain. The IF section and the digital section will be common between GPS and cellular/PCS. The digital section will have hardware correlators to process the GPS signal in real time. Thus, the hardware correlators will get timing and frequency control signals to speed up the GPS acquisition process.

9. CONCLUSIONS

The proposed location determination technology uses measurements from the cellular/PCS network and GPS constellation. This hybrid approach is best suited to support location services. It will improve accuracy and availability in scenarios where infrastructure-based solution only or GPS-based solution only will have problems. In addition, the signals from the GPS system are available free of charge world-wide and have a high degree of reliability.

The proposed solution will have the following advantages:

1. Allows computation of MS position when fewer than four satellites are visible.
2. Provides better availability, since it merges the coverage areas of infrastructure-based and GPS-based approaches.
3. Improves signal-to-noise ratio and permits operation of the system in urban canyons and high rise buildings. In addition, it may result in lower antenna subsystem cost.

4. Takes advantage of the CDMA phone's knowledge of time.
5. Allows for the use of the serving BS location and the round trip delay between the BS and the wireless phone in determining the latter's position.
6. Allows for the use of mobile measurements such as pilot strength and pilot phase.
7. Gives differential correction capability.
8. Uses existing hardware correlators and software searchers already implemented in the CDMA MS.
9. Uses search window size to reduce search time in the code domain.
10. Narrows the search window in the frequency domain since the CDMA wireless unit is continuously tracking the BS frequency.
11. Eliminates the need for additional server functionality since the PDE functionality could be provided by the base station control (BSC).
12. Allows continuous tracking after initial position is obtained using a hybrid technique. During tracking only a few and infrequent GPS measurements are needed.

GLOSSARY OF TERMS

ALI - Automatic Location Identification: Location information database that includes address data and other information about the caller.

ANI - Automatic Number Identification: A loose definition is the telephone number of the subscriber.

AOA - Angle of Arrival: The direction of the incoming signal with respect to some reference point.

BS - Base Station: An element of the cellular/PCS network.

BSC - Base Station Control: An element of the cellular/PCS network.

DGPS - Differential GPS: Means to correct common sources of errors in GPS.

ESN - Emergency Service Network: Network that handles E911 calls.

GPS - Global Positioning System: A group of satellites orbiting the earth used primarily for location and time services.

MS - Mobile Station: Any wireless telephone or terminal.

MIN - Mobile Identification Number:

MSC - Mobile Switching Center: An element in the cellular/PCS network.

PDE - Position Determination Entity: A computer attached to the BSC to calculate mobile station position.

PLA - Position Location Application: An application that utilizes position location data.

PN - Pseudo Noise: Noise-like code generated using linear shift registers.

PR - Pseudorange: Range between GPS satellites and GPS receiver including clock bias.

PSAP - Public Safety Answering Point: The E911 call taker handling an E911 call. This is the termination point of the E911 call.

RMS - Root Mean Square: Square root of the second central moment of a random variable.

RTD - Round Trip Delay: The time it takes the signal to travel back and forth between the mobile and base stations.

SMR – Specialized Mobile Radio: - A rapidly growing wireless application originally set up to provide local dispatch service. It has a different network architecture compared to cellular/PCS.

TDOA - Time Difference of Arrival: Difference between the times it took the signals from one radio source to travel to two different receivers.

CERTIFICATE OF SERVICE

I, Susanne M. Gyldenvand, hereby certify that on this 30th day of July, 1999, copies of the foregoing *ex parte* letter regarding CC Docket No. 94-102, in response to DA 99-1049, were served by hand upon the following:

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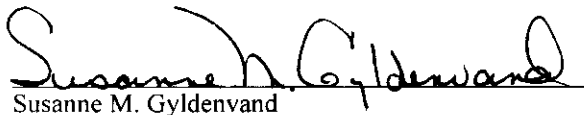
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